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APPLICATION OF MATRICAL BOOLEAN ALGEBRA TO THE ANALYSIS AND SYNTHESIS OF RELAY-CONTACT SCHEMES

A. G. Lunts
Submitted by Acad A. N. Kolmogorov

In the past, Boolean algebra has been employed successfully in the analysis and synthesis of relay-contact electrical schemes of parallel-series connection (vide L. Kutyura's Algebra of Logic, 1909; V. Shestakova in Avtomatika i Telemekhanika, 2, 15, 1941; M. A. Gavrilov in Elektrichestvo, 2, 54, 1946). This method, however, seems insufficient for the theory of schemes of a general type, and also for the theory of multipolar, or multiterminal, schemes. In the present article it is proposed that matrical Boolean algebra be employed for investigations of this kind; some results obtained in this direction are described.

Matrical Boolean Algebra

Let A* be a certain Boolean algebra (vide Kutyura's Algebra of Logic). Consider matrices with elements from A*. As for ordinary matrices (with elements from a field), for matrices with elements from A* it is possible to introduce the operations addition and multiplication, which we shall write: $A+B$ and $A \cdot B$. Also, associative, commutative (for addition), and distributive laws will hold true here.

Let us introduce the notion of a "determinant" for a quadratic matrix with elements from A* as a sum of factorial-n (n!) terms, composed in the same manner as in an ordinary determinant of the n-th order. Such determinants will possess a number of properties analogous to those of ordinary determinants.

For a pair of matrices with elements from A* we introduce another operation, "Boolean multiplication," designated as $A \cdot B = C$, and determine the elements of the matrix C through the elements of the matrices A and B in the following manner:

$$c_{a,b} = a_{a,b} \cdot b_{a,b}$$

for all indices a and b.

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The quadratic matrix with elements from A*, whose main diagonal consists of unities, shall be called a "Boolean"; and the set of Boolean matrices of the n-th order with elements from A* shall be designated by the symbol A_n^* and be called a matrical Boolean algebra. The set A_n^*, as a matter of fact, is a Boolean algebra relative to the operations of addition and Boolean multiplication. Hereafter, we shall have to deal only with matrices of A_n^*.

Multipolars

One can specify each relay-contact scheme (or part of a scheme) by indicating the direct conductivity between its points of juncture. Therefore, in the electrical scheme under study, we select n points (poles) M_1, M_2, ... M_3 and study the scheme relative to these points. Designate the direct conductivity from pole M_a to pole M_b by $a_{a,b}$ (a, b = 1, 2, ... n). This symbol $a_{a,b}$ represents the sum of conductivities of all possible elementary circuits in the scheme that go from pole M_a to pole M_b passing through the remaining poles. It is essential to set $a_{a,a}$ equal to unity (a = 1, 2,....n). These n^2 quantities are written in the form of a Boolean matrix.

$$A = \begin{matrix} a_{11} & a_{12} & \ldots & a_{1n} \\ a_{21} & a_{22} & \ldots & a_{2n} \\ a_{n1} & a_{n2} & \ldots & a_{nn} \end{matrix}$$

If tube elements are absent in the electrical scheme, then the matrix A will be symmetrical. As already indicated, the matrix A, in a certain relation, characterizes the structure of the electrical scheme. Each electrical scheme with n selected and "renumbered" poles, the direct conductivities between which form the matrix A, will be called "n-polar A."

Designate by $k_{a,b}$ (A) the total conductivity from pole M_a to pole M_b. Thus $k_{a,b}$ (A) is the sum of conductivities of all elementary circuits in the scheme, going from pole M_a to pole M_b. The n^2 quantities $k_{a,b}(A)$(a,b = 1,2, ...n) form the Boolean matrix

$$k(A) = \begin{matrix} k_{11}(A) & k_{12}(A) & \ldots & k_{1n}(A) \\ k_{21}(A) & k_{22}(A) & \ldots & k_{2n}(A) \\ k_{n1}(A) & k_{n2}(A) & \ldots & k_{nn}(A) \end{matrix}$$

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